The eRHIC Detector: Design and Realization

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Fall Meeting of the APS Division of Nuclear Physics

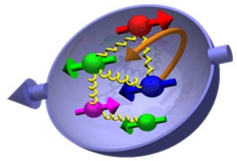
October 24-27, 2012; Newport Beach, California

Overview

- Physics motivation
- Status of the project:
  - The collider
  - The interaction point
  - The detector
- Conclusions
- Links for other documentation

Physics motivations

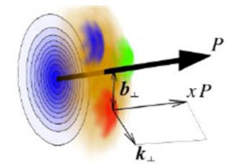
spin physics



- what is the polarization of gluons at small x where they are most abundant
- what is the flavor decomposition of the polarized sea depending on x

determine quark and gluon Contributions to the proton spin at last

imaging

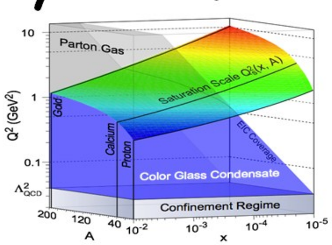


- what is the spatial distribution of quarks and gluons in nucleons/nuclei
- understand deep aspects of gauge theories revealed by k_T dep. distr'n

possible window to orbital angular momentum

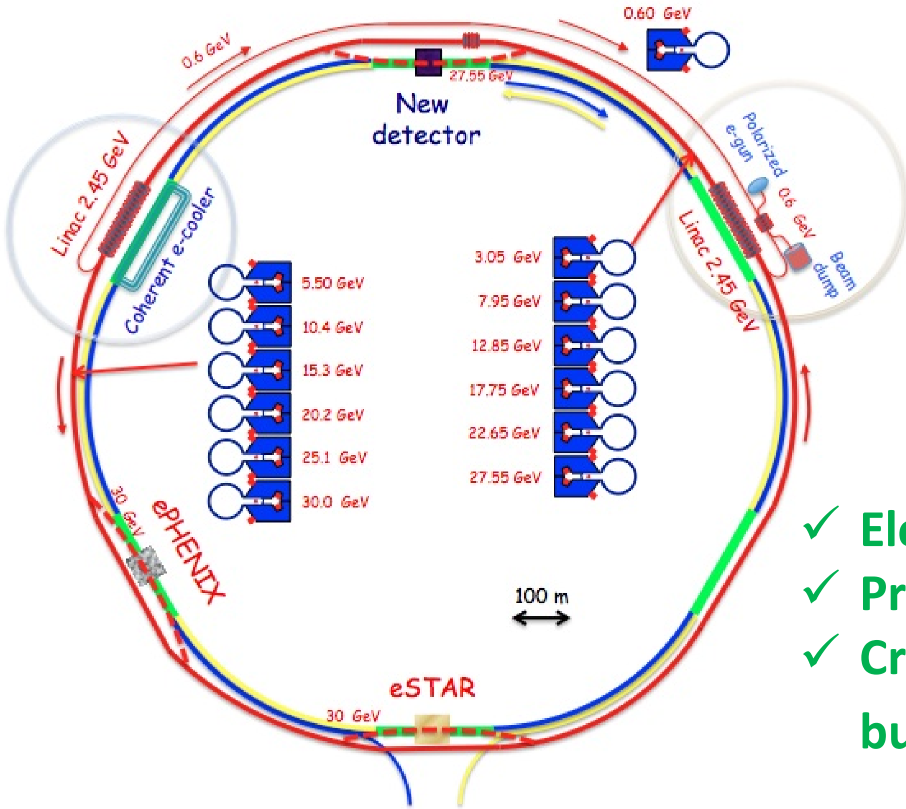
physics of strong color fields

quantitatively probe the universality of strong color fields in AA, pA, and eA



- understand in detail the transition to the non-linear regime of strong gluon fields and the physics of saturation
- how do hard probes in eA interact with the medium

Accelerator complex



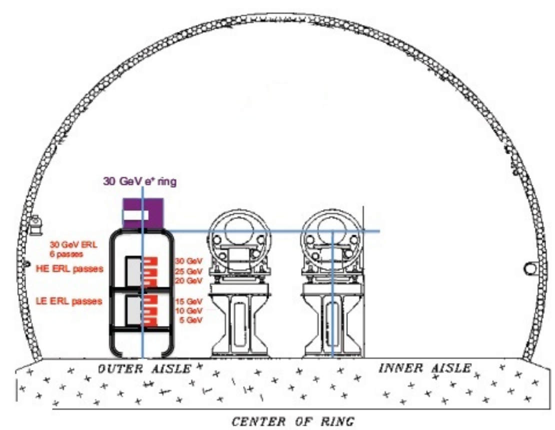
Collisions:

- ✓ **Polarized electrons : 5, 10, 20, (30?) GeV**
- ✓ **Polarized protons :75, 250 Gev**
- ✓ **Ions. 50, 100 GeV/u**

Keypoints:

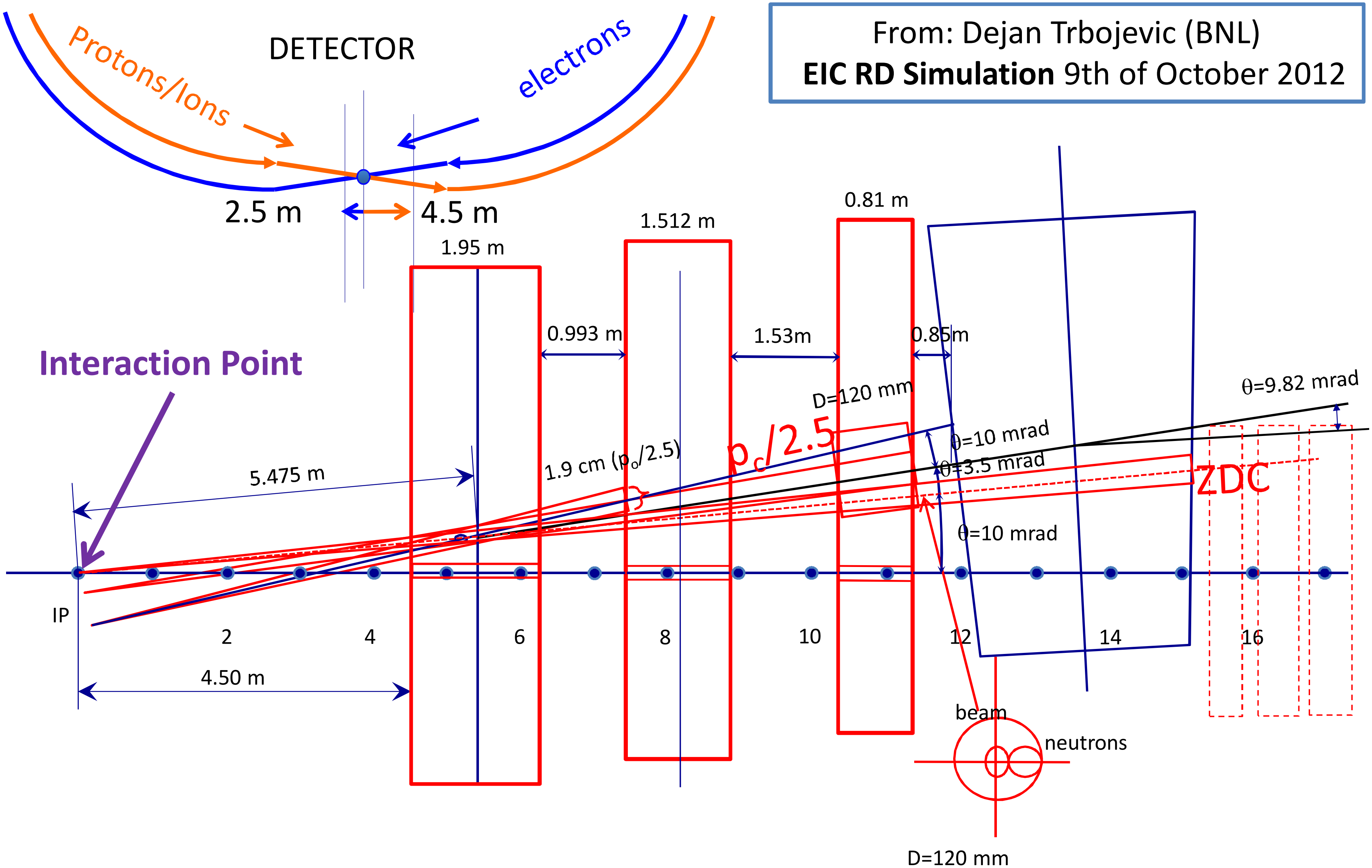
- ✓ **Electrons beam: New High Energy ERL.**
- ✓ **Protons beam: electron cooling.**
- ✓ **Crab Crossing Cavities to restore Head to head bunches collisions .**

- ✓ **No other tunnel required: electrons beam line will be added in the present RHIC tunnel.**
- ✓ **Up to 3 experimental locations .**

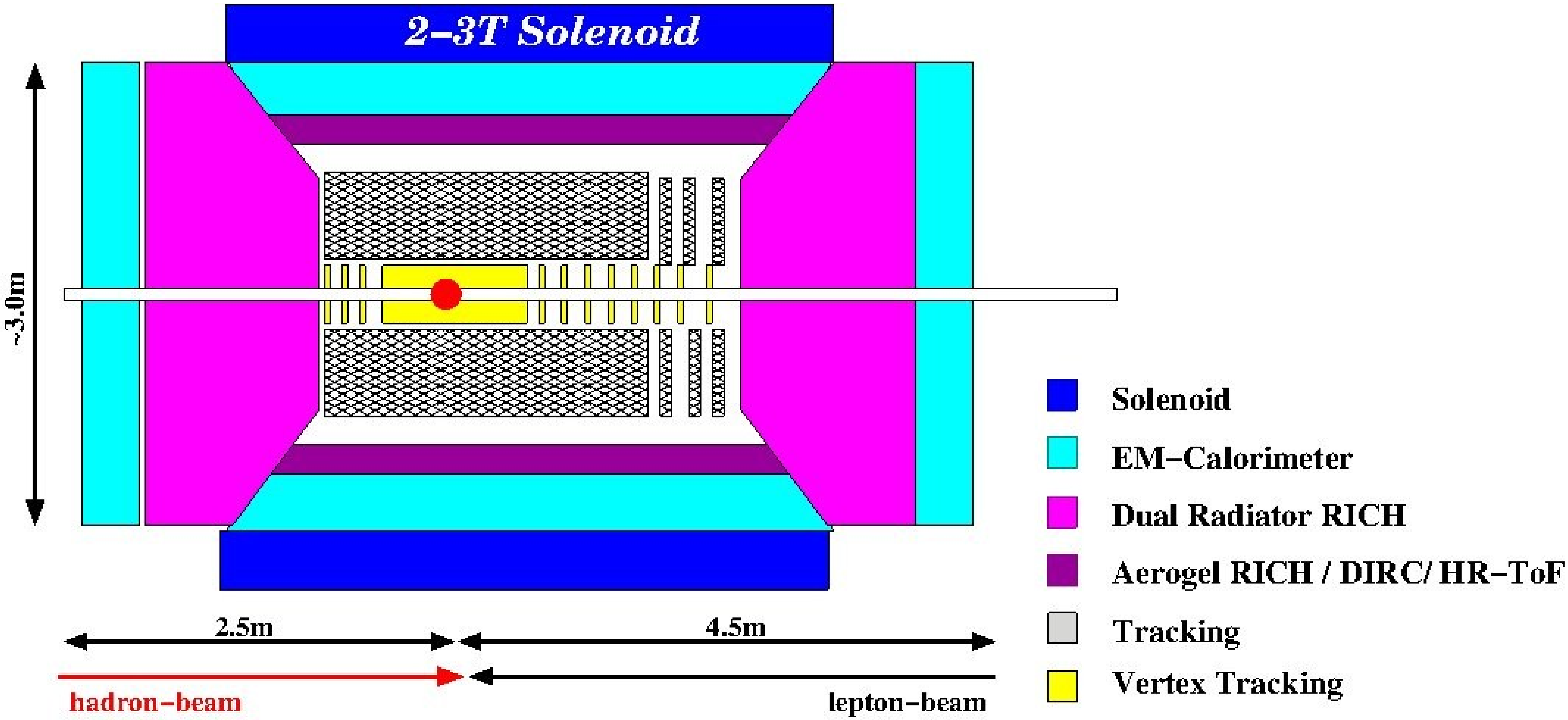


IP configuration for eRHIC

From: Dejan Trbojevic (BNL)
EIC RD Simulation 9th of October 2012



Overview of the New Detector



good PID (π,K,p and lepton) and vertex resolution (< 5μm)
tracking and calorimeter coverage the same → good momentum resolution, lepton PID
low material density → minimal multiple scattering and brems-strahlung
very forward electron and proton/neutron detection → maybe dipole spectrometers

Overview of the New Detector

- Si-Vertex
  - MAPS technology from IPHC ala STAR, CBM, Alice, …)
    - Barrel:

    4 double sided layers @ 3. 5.5 8. 15. cm 10 sectors in Φ
    - Forward Disks:

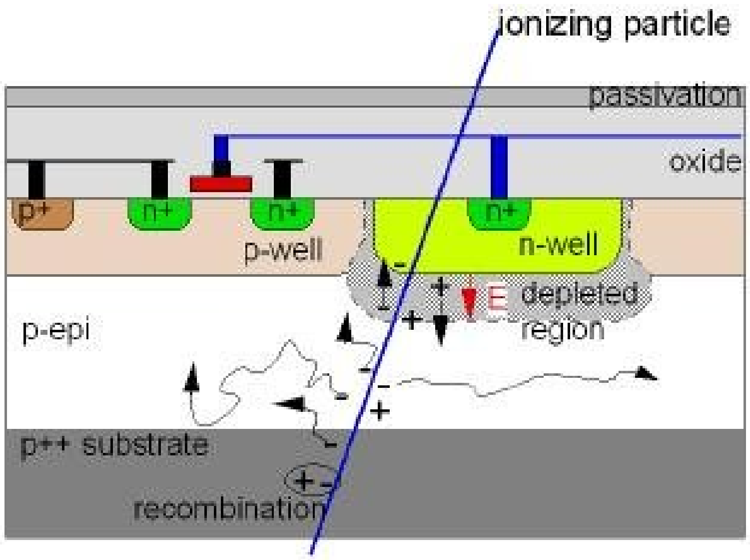
    4 single sided disks spaced in z starting from 20 cm, dual sided readout ?
- Barrel Tracking
  - Preferred technology TPC (alternative GEM-Barrel tracker Mass?)
    - Low mass, PID e/h via dE/dx
- Forward tracking
  - GEM-Trackers
- Forward/Backward RICH-Detectors
  - Momenta to be covered: 0.5-80 GeV for $1<|y|<4(5)$
  - Technology:
    - Dual Radiator (HERMES, LHCb) Aerogel+Gas (C_4F_{10} or C_4F_8O)
  - Photondetector: low sensitivity to magnetic field

Overview of the New Detector

- Barrel PID-Detectors
  - Momenta to be covered 0.5-10 GeV for -1<y<1
  - Technology:
    - Aerogel Proximity focusing RICH
    - DIRC
- ECal:
  - Backward/Barrel:
    - PbW-crystal calorimeter → great resolution, small Molière radius → electron-ID: e/p, measure lepton via Ecal, important for DVCS
  - Forward:
    - Less demanding: sampling calorimeter
- Preshower
  - Si-W technology as proosed for PHENIX MPCEX
- Hcal/Muons-Detectors
  - Not obvious they are really needed
- Luminosity monitor, electron and hadron polarimeters

Silicon Vertex

Vertex system based on Monolithic Active Pixel Silicon Sensor (MAPS)



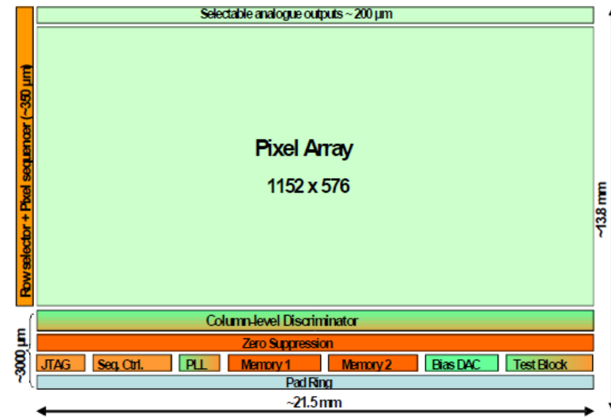
Tests ongoing in BNL and Columbia University on MAPS Mimosa 26 prototypes designed in Institut Pluridisciplinaire Hubert Curien,Strasburg.

Keypoints:

- ✓ **All the sensor is produced using a standard CMOS technology.**
- ✓ **Works at room temperature: low cooling material budget.**
- ✓ **Low bias voltage required: electrons are collected for thermal diffusion.**
- ✓ **High resolution.**

Silicon Vertex

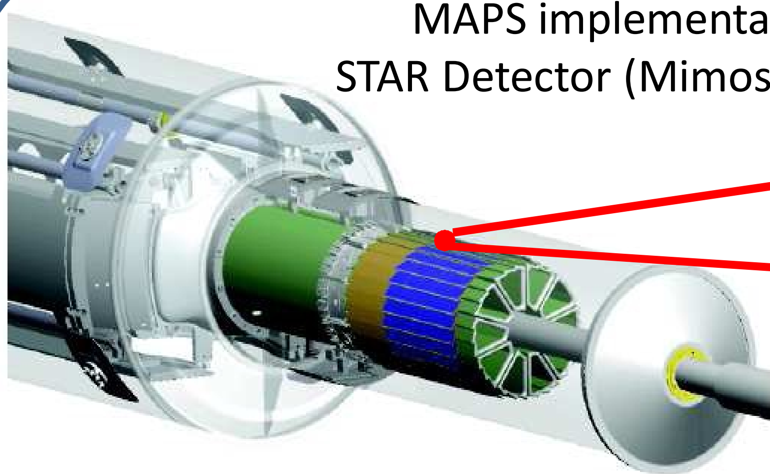
Mimosa 26 :

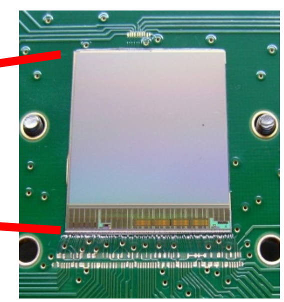


- ✓ Matrix of 663 552 pixels: 576 lines x 1152 col.
- ✓ 13.7 mm X 21.5 mm Matrix Surface
- ✓ Pitch= 18 μm
- ✓ Sensitive volume thickness 15 μm
- ✓ Digital data stream after zero suppression

See for details: http://www.iphc.cnrs.fr/List-of-MIMOSA-chips.html

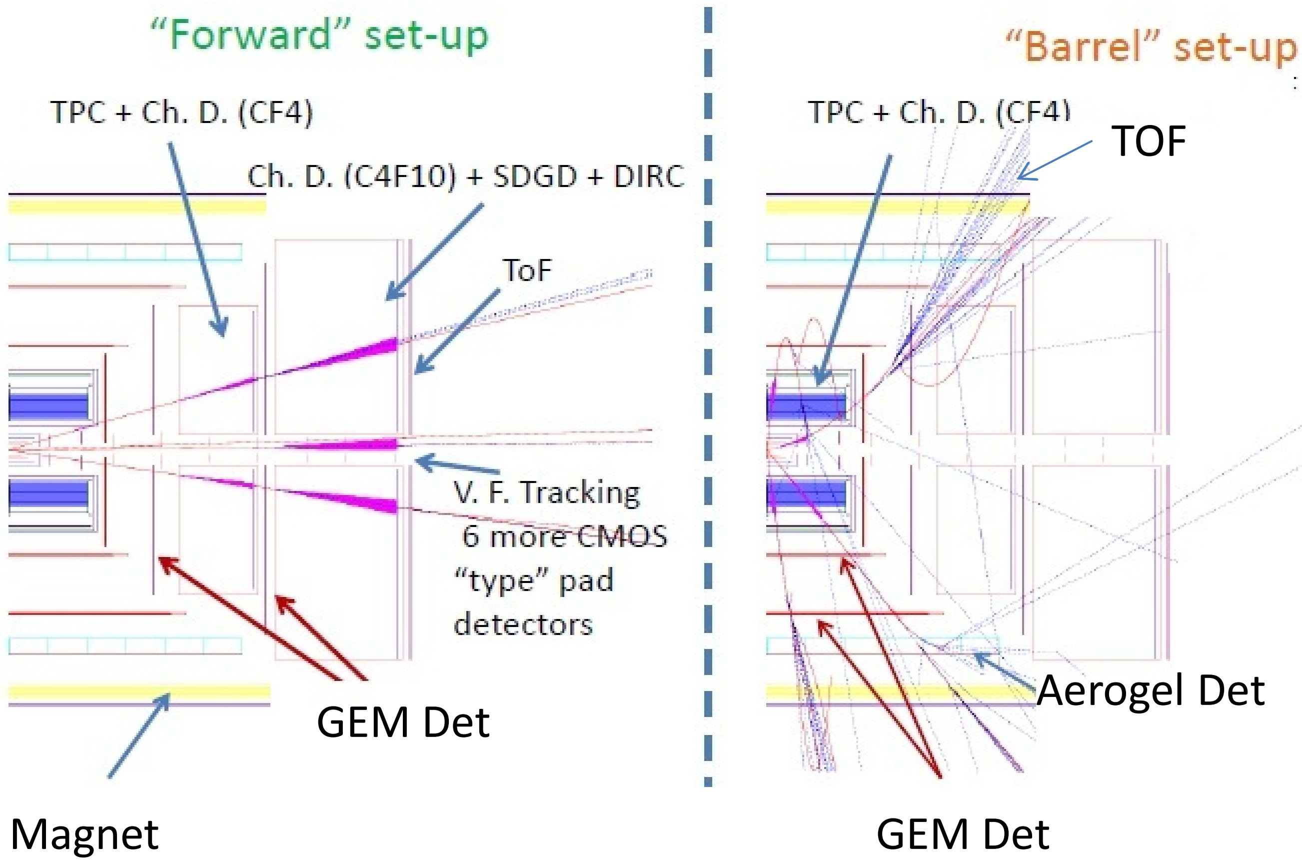
MAPS implementation in the STAR Detector (Mimosa 28 Ultimate)





https://indico.bnl.gov/getFile.py/access?contribId=30&resId=0&materialId=slides&confId=521dd

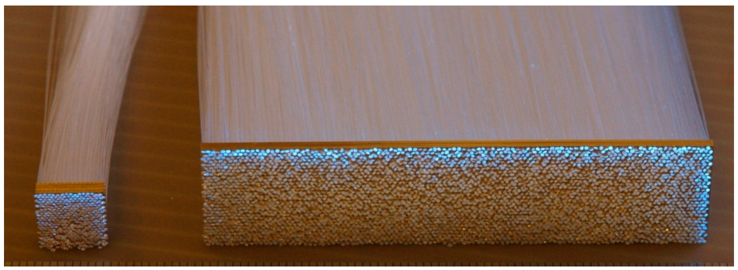
Tracking System



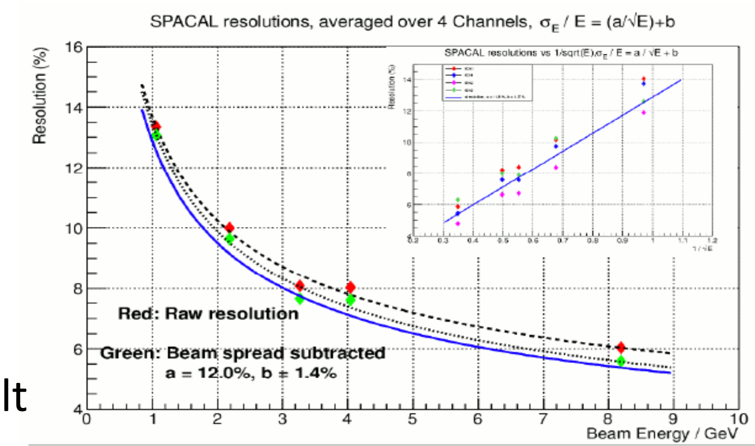
Calorimeters

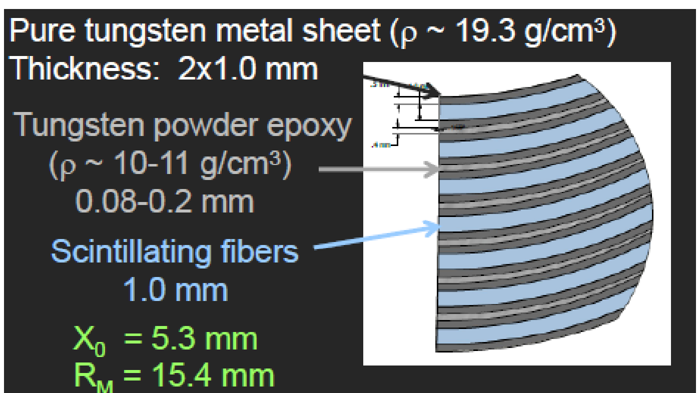
New technologies under consideration:

STAR Forward Calorimeter:Tungsten Powder/Epoxy/SciFi
O. Tsai, H. Huang (UCLA)

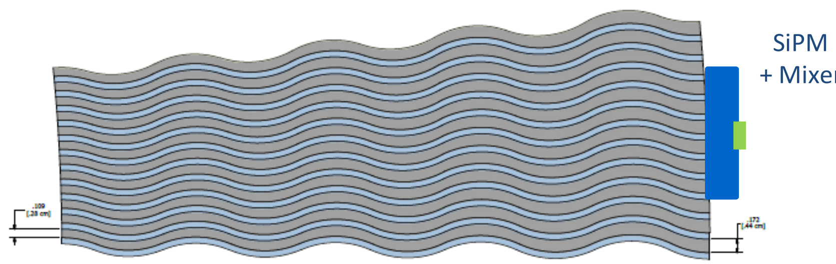


Fermilab Test Beam result





Tungsten-Scintillating Fiber
"Optical Accordion" EM Calorimeter

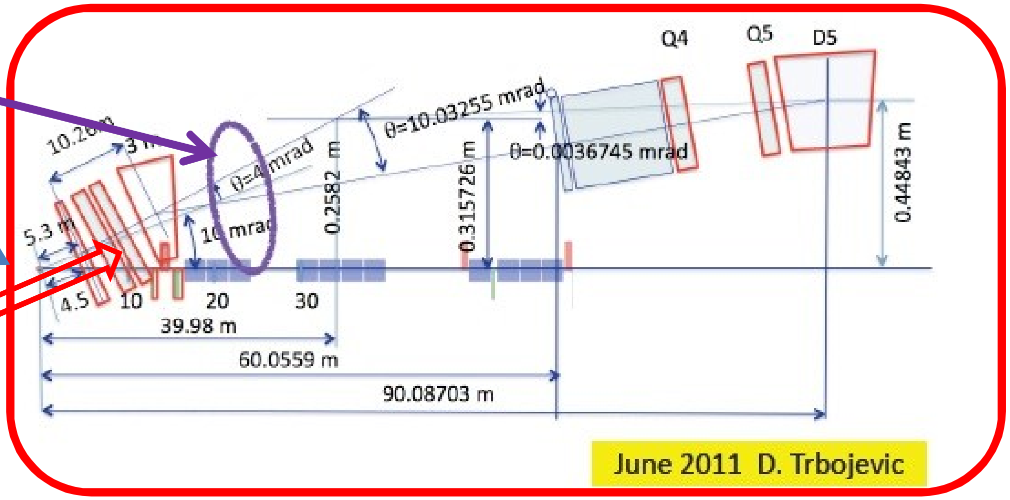


Roman Pots Studies

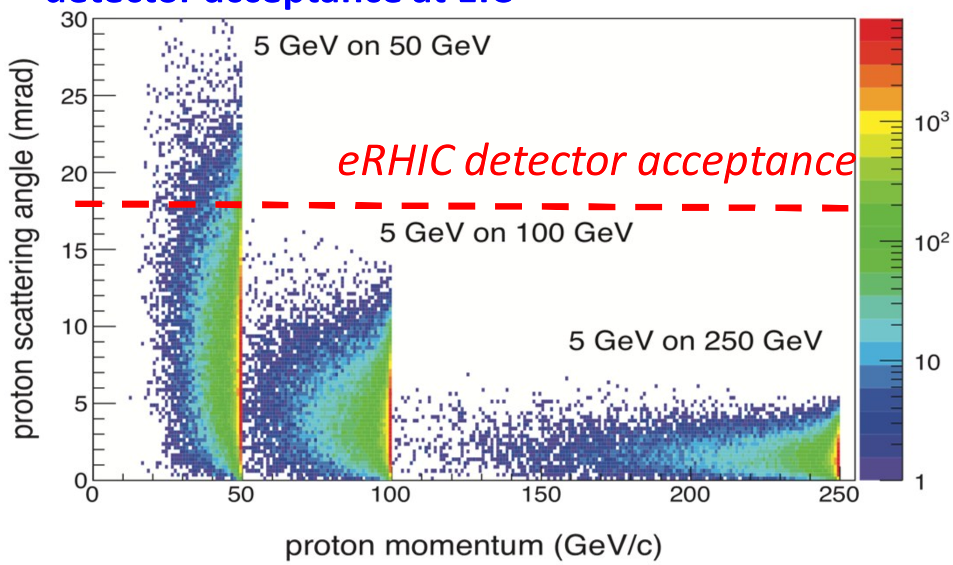
Roman Pots station (20 – 22 m from IP)

Interaction Point

Hadron Beam Direction

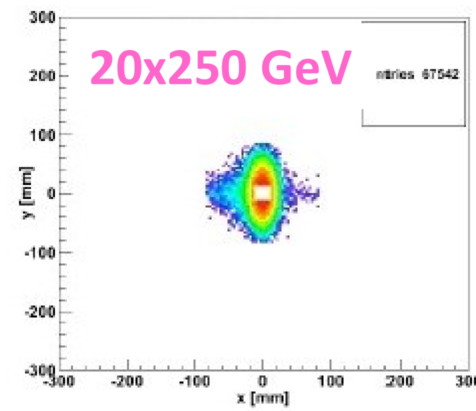


leading protons are never in the main detector acceptance at EIC



Main detector

Roman Pots



Conclusions

- The Physics case for e/A collider is well established: with this machine we can answer to a lot of question still opened on Nucleon and Ions Spin structure.
- The design for a electron/Ion collider and a new detector in BNL is in good shape.
- A lot of research is ongoing in order to find new and original solution s for the new facility.

Thanks for your attention !

And don't forget: Since October 15th 2012 is available the

EIC White Paper

http://skipper.physics.sunysb.edu/~abhay/eicwp12/Main.html

Still preliminary version, comments are welcome

(click on "Chapter N" then look for the files "master-wp-chptN.pdf")

Other talks on the same topic in this conference

Other talks in this conference on this topic:

- **Mattew Lamont** (Brookhaven National Laboratory)

Measuring the gluon distribution of nuclei: diffractive e+A collisions at eRHIC

Session DE: Heavy Ions; 11:42 AM–11:54 AM, Thursday, October 25, 2012

- **Aidala Cristina** (University of Michigan)

Entering the Electronic Age at RHIC: eRHIC

Session 1WB: Hadron Physics IV;10:00 AM–10:30 AM,Friday, October 26, 2012

- **Thomas Burton** (Brookhaven National Laboratory)

eRHIC as a Nucleon Tomograph

Session PE: Hadron Physics IV; 11:42 AM–11:54 AM, Saturday, October 27, 2012

- **Liang Zheng** (Brookhaven National Laboratory)

Dihadron Correlation in the eA program at an Electron Ion Collider

Session PE: Hadron Physics IV; 11:30 AM–11:42 AM, Saturday, October 27, 2012

Other links

- Call for EIC proposal

https://wiki.bnl.gov/conferences/index.php/EIC_R%25D

- **eRHIC BNL home page**

https://wiki.bnl.gov/eic/index.php/Main_Page

- **eRHIC BNL Collider Accelerator Department**

http://www.bnl.gov/cad/eRhic/

- **EIC Montecarlo page**

https://wiki.bnl.gov/eic/index.php/Simulations

- **EIC R&D Simulation workshop (BNL October 8TH -9TH 2012)**

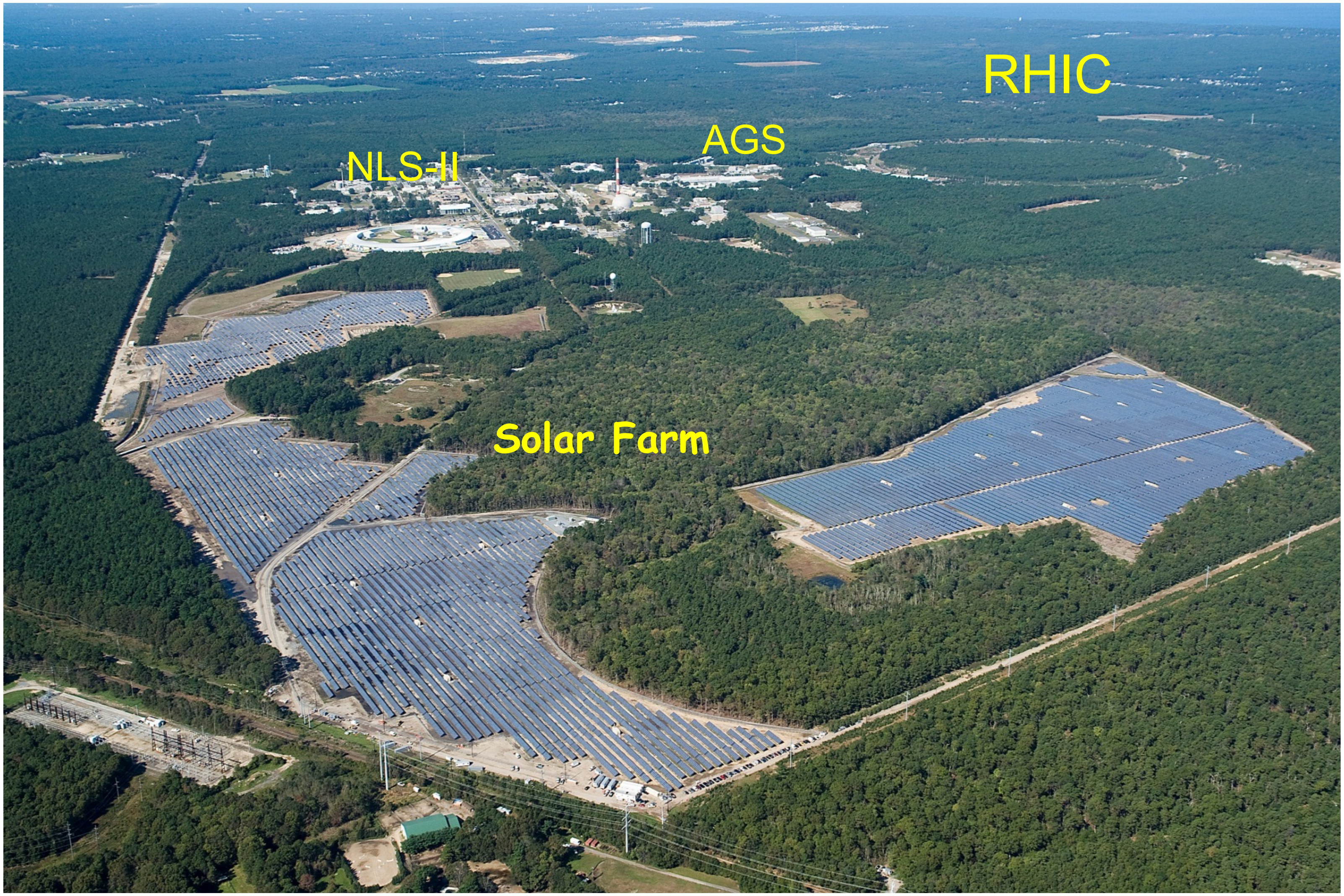
https://wiki.bnl.gov/conferences/index.php/EIC_RD_Simulation/Agenda

- **Gluons and quark sea at high energies:**

Report on a ten week program that toke place at the Institute for Nuclear Theory (Seattle, Fall 2010)
http://:arxiv/abs/1108.1713

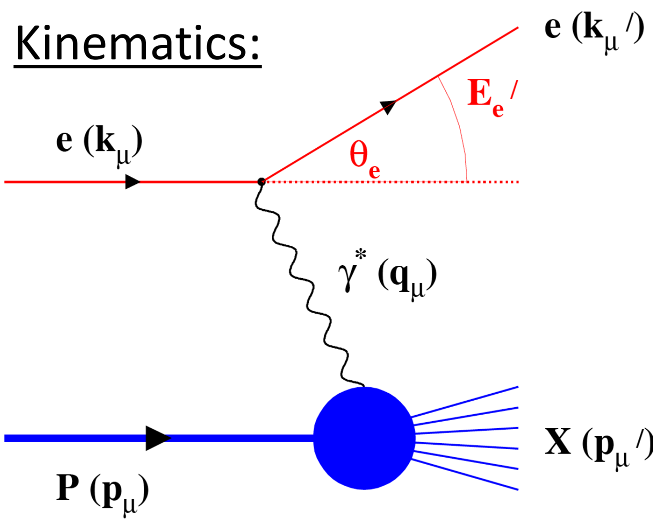
BACK-UP Slides

Brookhaven National Laboratory



How to see the gluons: Deep Inelastic Scattering

Kinematics:



$$Q^2 = -q^2 = -(k_\mu - k_\mu')^2$$
$$Q^2 = 2E_eE_e'(1-\cos\Theta_{e'})$$

Measure of resolution power

$$y = \frac{pq}{pk} = 1 - \frac{E_e'}{E_e}\cos^2\left(\frac{\theta_e'}{2}\right)$$

Measure of inelasticity

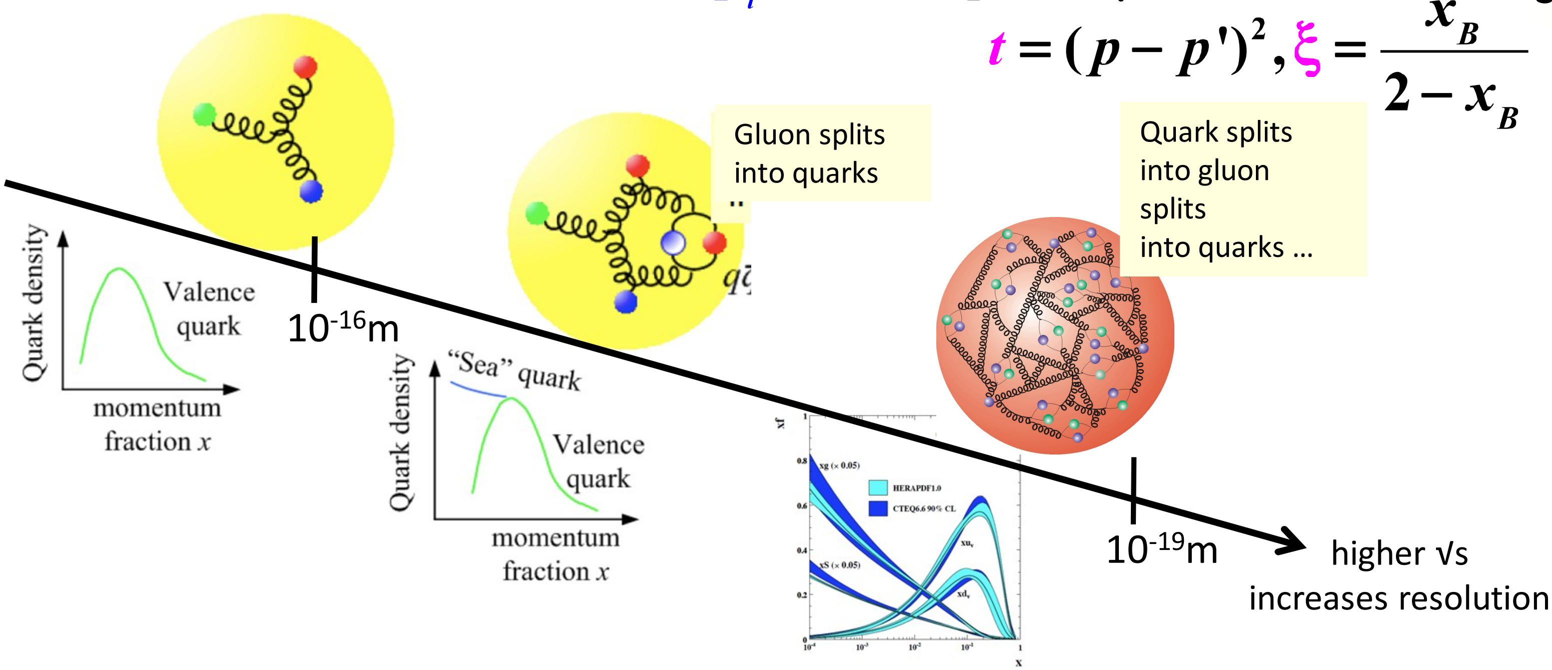
$$Hadron: z = \frac{E_h}{\nu};$$

$$x_B = \frac{Q^2}{2pq} = \frac{Q^2}{sy}$$

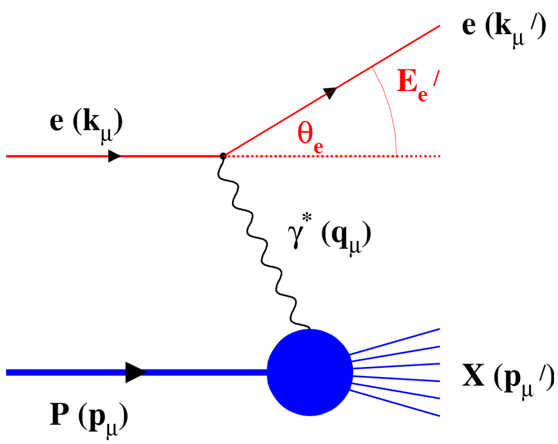
Measure of momentum fraction of struck quark

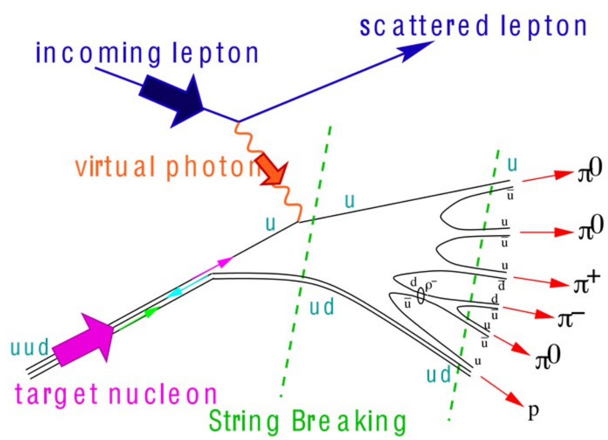
p_t^h: with respect to γ^*

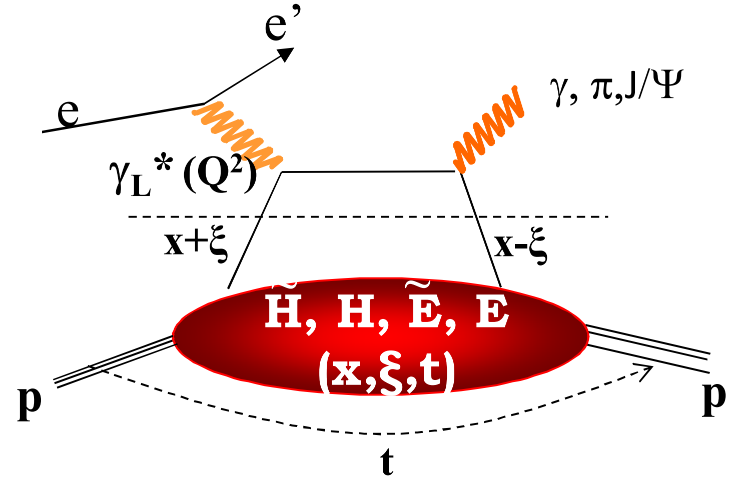
$$t = (p-p')^2, \xi = \frac{x_B}{2-x_B}$$



What needs to be covered







Inclusive Reactions:

- Momentum/energy and angular resolution of e' critical
- Very good electron id
- Moderate luminosity $>10^{32}$ cm^{-1} s^{-1}
- Need low x ~10^{-4} → high √s (Saturation and spin physics)

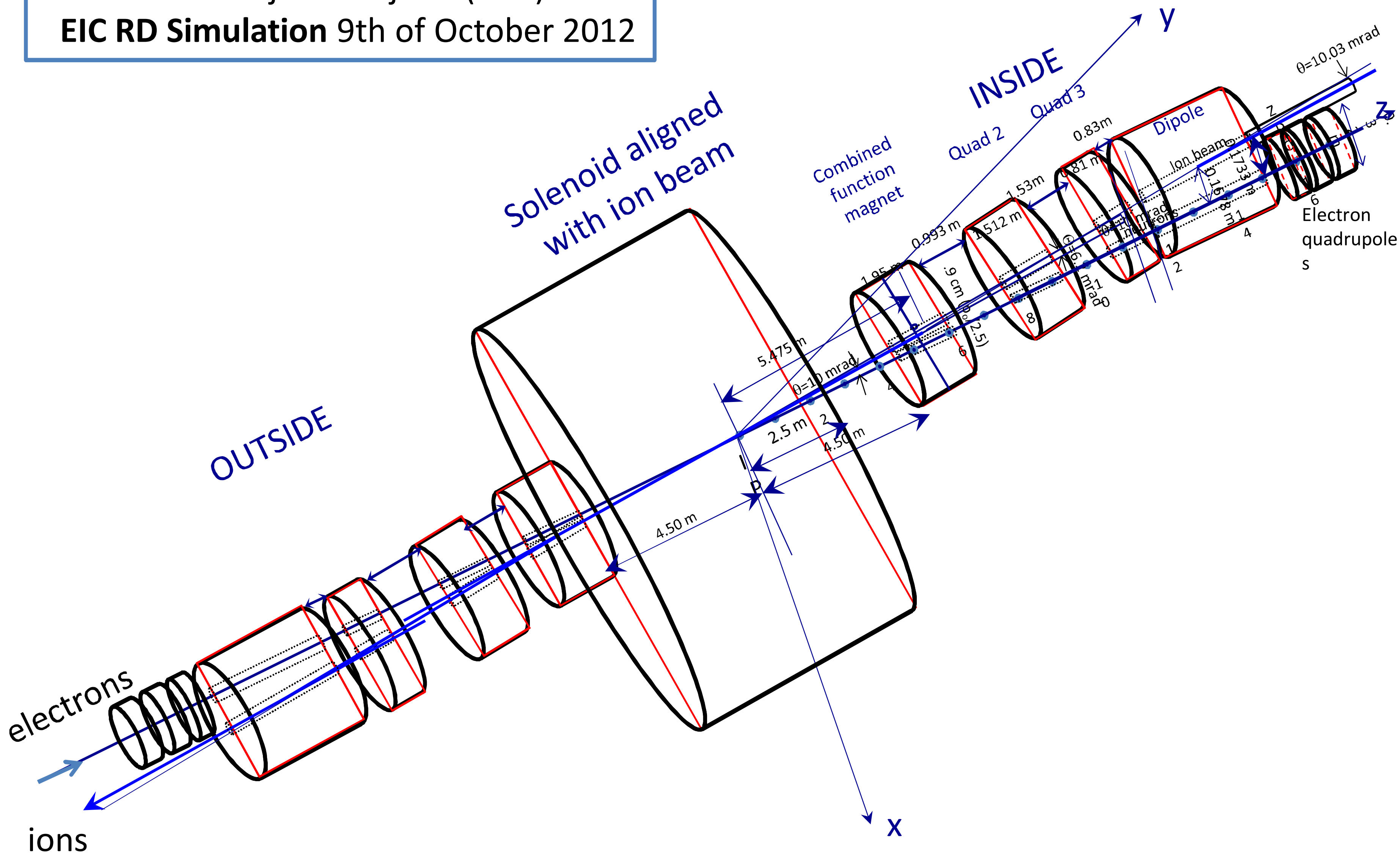
Semi-inclusive Reactions:

- Excellent particle ID: π,K,p separation over a wide range in η
- full Φ-coverage around γ^*
- Excellent vertex resolution → Charm, bottom identification
- high luminosity $>10^{33}$ cm^{-1} s^{-1} (5d binning (x,Q^2,z,p_t,Φ))
- Need low x ~10^{-4} → high √s

Exclusive Reactions:

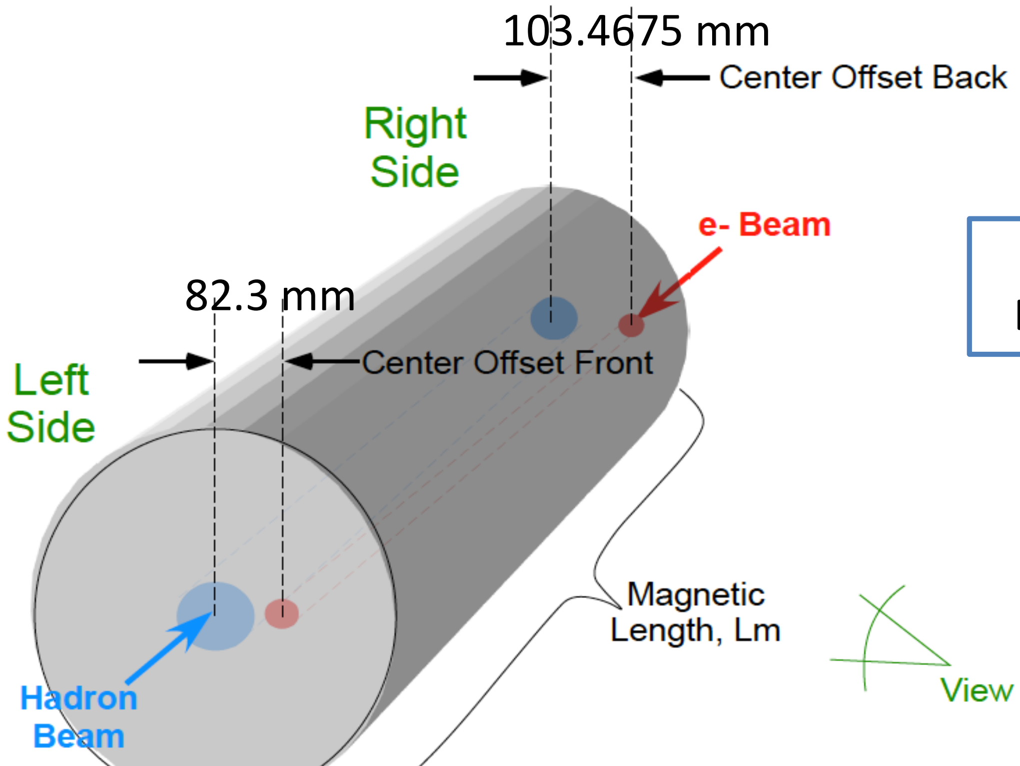
- Exclusivity → high rapidity coverage → rapidity gap events
- high resolution in t → Roman pots
- high luminosity $>10^{33}$ cm^{-1} s^{-1} (4d binning (x,Q^2,t,Φ))

From: Dejan Trbojevic (BNL)
EIC RD Simulation 9th of October 2012



Q2

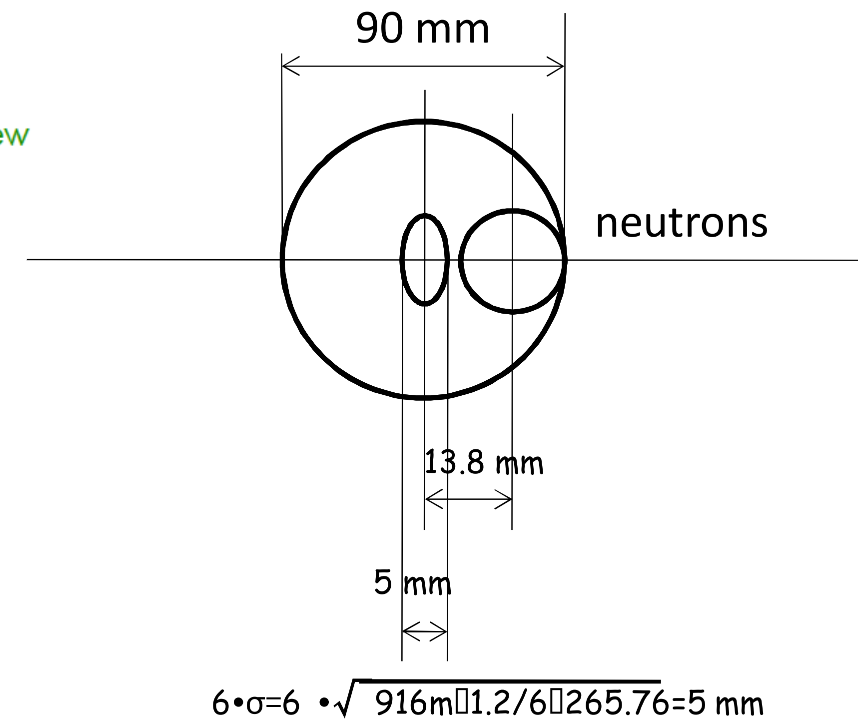
From: Dejan Trbojevic (BNL)
EIC RD Simulation 9th of October 2012



Lattice Optics Name =	
IR Location (Right/Left) =	Q2
Magnetic Length (m) =	left
Gradient (T/m) =	1.5157 m
Residual Field at e-Beam axis (Gauss) =	200 T/m
Hadron Beam Clear Bore Diameter (mm) =	1 G
Electron Beam Clear Bore Diameter (mm) =	90 mm
E-beam Center Offset Front (mm) =	18 mm
E-Beam Center Offset Back (mm) =	82.3 mm
	103.4675 mm

Name & Date filled Out ____________________

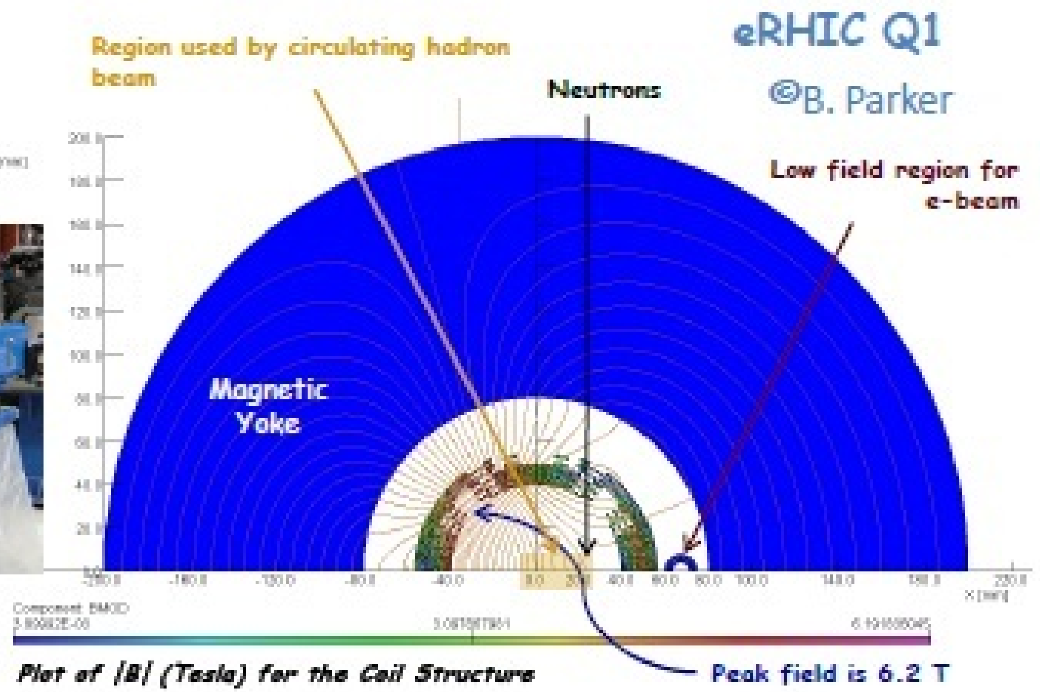
Hadron Aperture Q_2



The special IR magnet

- Large aperture for passage of neutrons and gammas, circulating beam and off-momentum charged particle.
- Based on Nb_3Sn magnet technology developed for LHC IR upgrade

LHC IR magnet prototype



From: Y.Hao on behalf of eRHIC design team
2012 RHIC & AGS Annual User's Meeting

eRHIC Collider parameters

	e	p	${}^{3}_{2}He$	${}^{197}_{79}Au$	${}^{238}_{92}U$
Energy, GeV	10	250	167	100	100
CM energy, GeV		100	82	63	63
Number of bunches/distance between bunches	107 nsec	111	111	111	111
Bunch intensity (nucleons)	$0.24 \cdot 10^{11}$	$4 \cdot 10^{11}$	$6 \cdot 10^{11}$	$6 \cdot 10^{11}$	$6.3 \cdot 10^{11}$
Bunch charge, nC	5.8	64	60	39	40
Beam current, A	0.05	0.556	0.556	0.335	0.338
Normalized emittance of hadrons 95% , mm mrad		1.2	1.2	1.2	1.2
Normalized emittance of electrons, rms, mm mrad		16	24	40	40
Polarization, %	80	70	70	none	none
RMS bunch length, cm	0.2	5	5	5	5
β*, cm	5	5	5	5	5
Luminosity per nucleon, $cm^{-2} s^{-1}$		**2.7×10^{34}**	**2.7×10^{34}**	**1.6×10^{34}**	**1.7×10^{34}**

Plots from J-H Lee

Roman Pots Studies